

Efforts to Ensure Levee Reliability

February 26, 2008

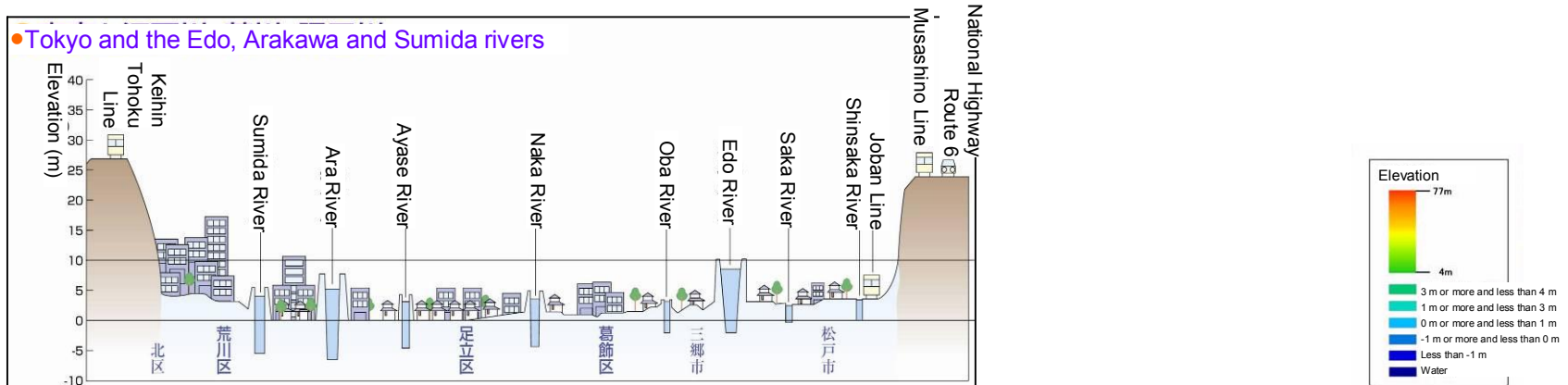
Hideo Tamura

Director, River Management Office,
River Improvement and Management Division,
River Bureau

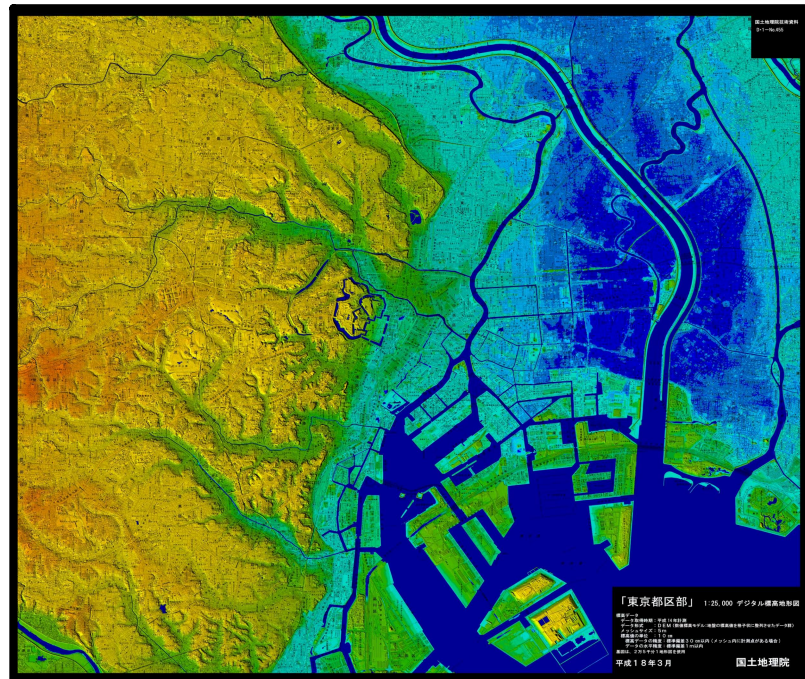
Contents

- Characteristics of levees in Japan
- Structural standards for levees
- Safety verification method for levees
(seepage, erosion, earthquake resistance)
- Monitoring of levees
(feedback from maintenance)

Characteristics of Levees in Japan



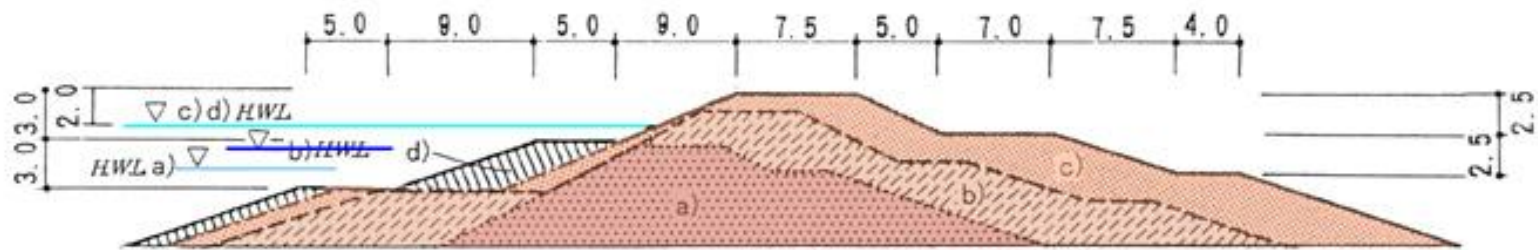
Population and property concentrated in coastal areas and low-lying areas



Source: data compiled by Geographical Survey Institute

Levees as Historical Structures

Levees that we see today are the results of various strengthening works carried out over many years.

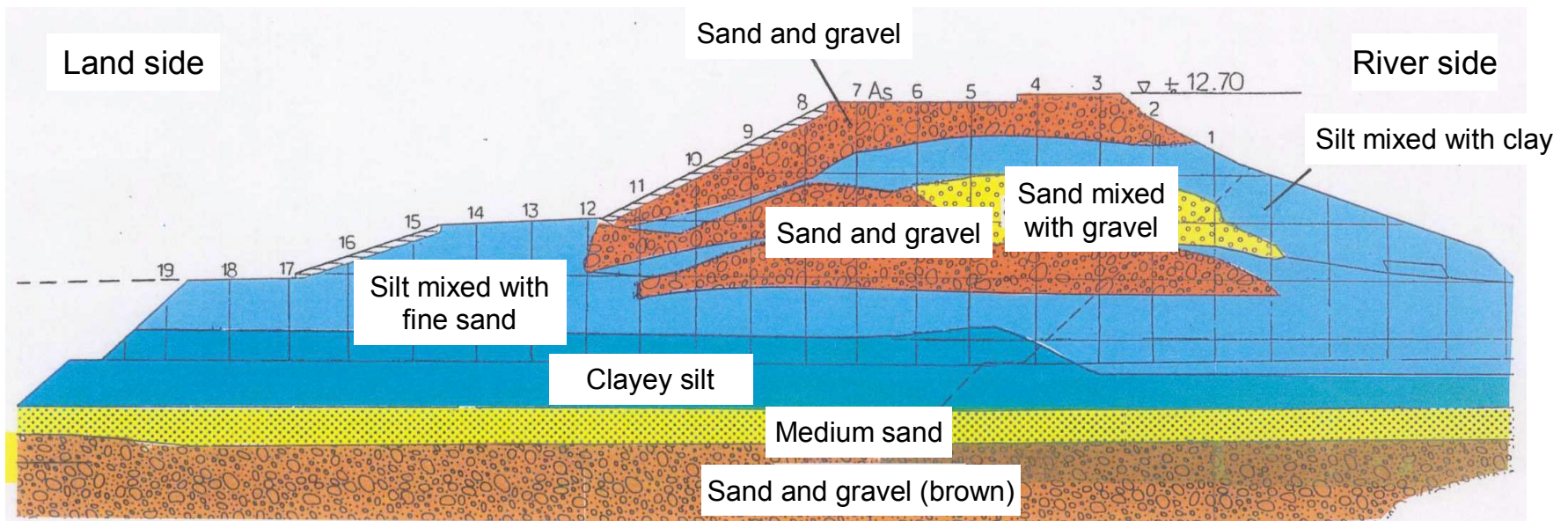


- a) Improvement Plan (1911)
- b) Augmentation Plan (1939)
- c) Modified Improvement Plan (1949)
- d) New Modified Improvement Plan (1980)

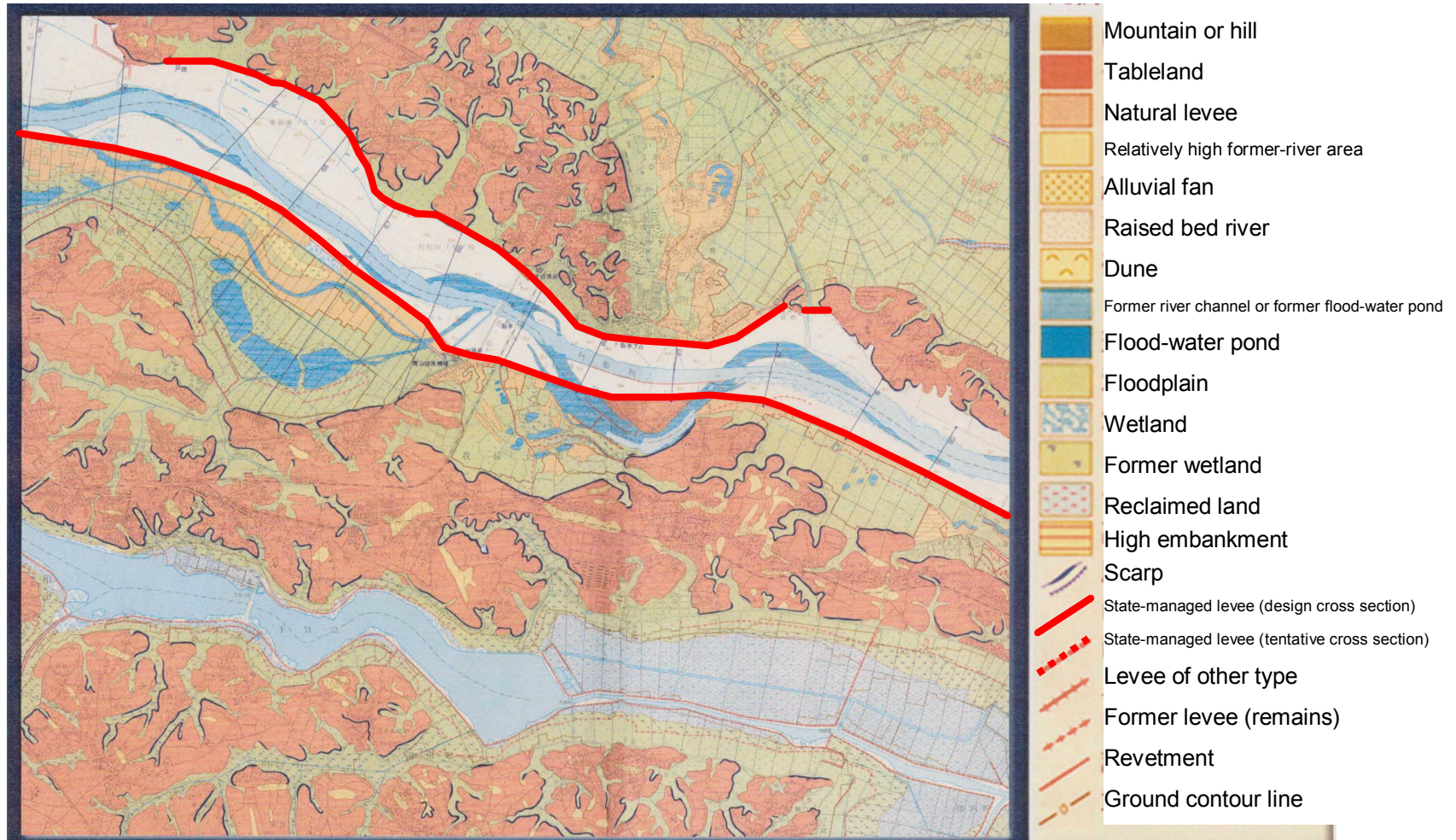
Historical changes in the cross section of the Edo River

Complexity of levee materials

Levees have been built mainly with locally available materials. Consequently, soil types (levee materials) and construction methods (e.g., compaction) used are diverse.



Diverse composition of foundation ground



Example of landform classification map for flood management*

* A map showing details of landform classification in a river area (compiled from 1976 to 1978)

Structural Standards for Levees

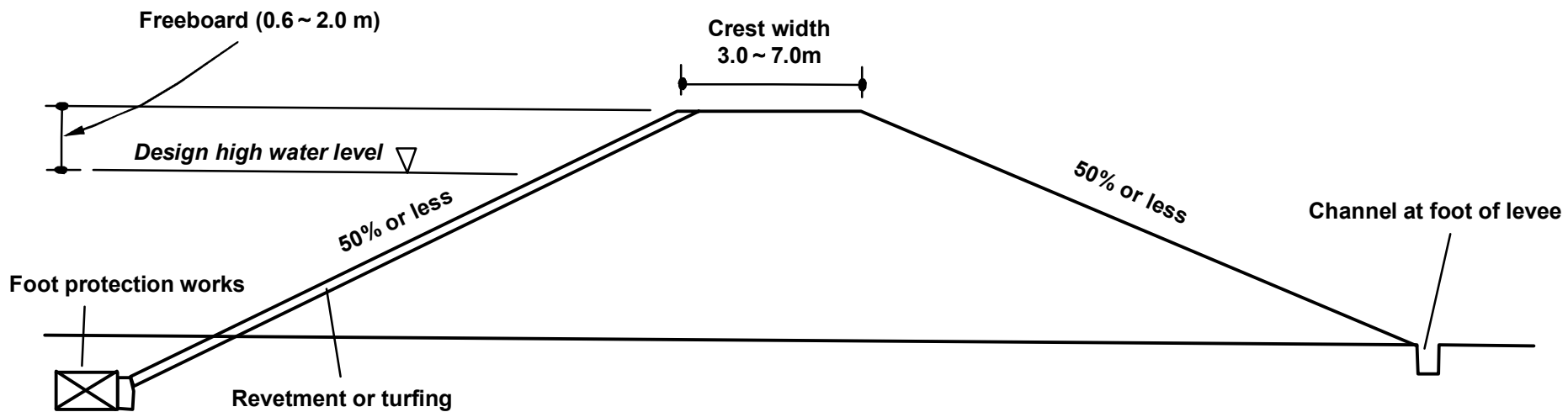
- Cabinet Order Concerning Structural Standard for River Administration Facilities, Etc. (Cabinet order, 1976)
The minimum standards (e.g., height, crest width, slope gradient) for levee geometry appropriate for river sizes are stipulated.
- Technical Standard for River Works (circular of the Director General of River Bureau, revised in 1997)
Basic concepts for the determination of levee structure based on engineering knowledge are indicated.
- Guideline for Levee Design (circular of the Director of River Improvement and Management Division, 2002)
Methods for determining levee structure based on engineering knowledge and criteria for verification are stipulated.
- Manual for Determination of Levee Structure (JICE document, 2002)
Safety verification methods and strengthening methods conforming to the Guideline for Levee Design are described.
- Guideline for Verification of Seismic Performance of River Structures (circular of the Director of River Improvement and Management Division, 2007)
Methods for verifying seismic performance against the maximum probable earthquake are specified.

Cabinet Order Concerning Structural Standard for River Administration Facilities, Etc.

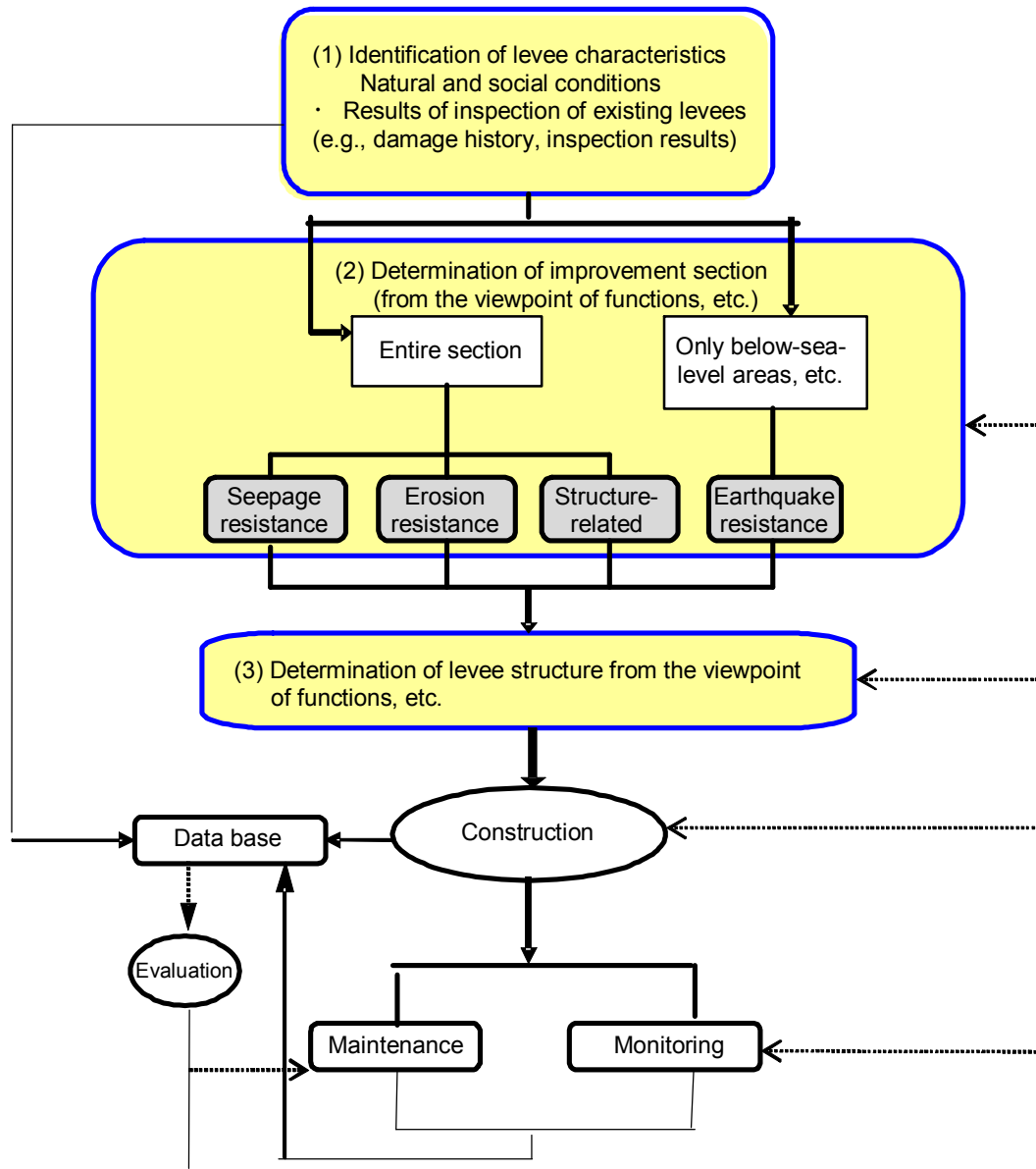
(geometrical requirements)

- Safe structure against the action of flowing water at or below HWL
- Earth levee (as a general rule)
- Height (height over HWL to be determined according to streamflow)
- Crest width (specified according to streamflow)
- Slope gradient: 50% or less; slope protection by turfing, etc.

Standard Levee Structure Conforming to Cabinet Order Concerning Structural Standard for River Administration Facilities, Etc.



Basic Flow of Levee Design (Guideline for Levee Design 2002)



Summary Inspection of Levee Safety against Seepage (1996 ~)

Safety evaluation procedure

1. Evaluation based on factors

(1) Evaluation from the viewpoint of soil type conditions

Type of foundation ground material	Attention-requiring landform	Type of levee material		
		Clayey	Sandy	Gravelly
Clayey	No	a	c	b
	Yes	b	d	c
Sandy or gravelly	No	b	c	b
	Yes	c	d	c

(2) Evaluation from the viewpoint of external force conditions

Duration of high water level t (hr)	Average hydraulic gradient i					
	Less than 0.10	0.10 ~ 0.15	0.15 ~ 0.20	0.20 ~ 0.25	0.25 ~ 0.30	0.30 or more
$t < 24$	a	a	b	b	c	d
$24 \leq t < 48$	a	b	b	c	d	d
$48 \leq t$	b	c	c	d	d	d

Rating based on factors

Rating based on factors					
		(1) Evaluation from the viewpoint of soil type conditions			
		a	b	c	d
(2) Evaluation from the viewpoint of external force conditions	a	A	A	B	C
	b	A	B	B	C
	c	B	C	C	D
	d	C	C	D	D

2. Evaluation based on damage history

No
Damage history
Yes

Evaluation based on factors
As rated (A, B, C or D)

Evaluation based on factors
D regardless of rating

Summary rating safety

A: highly safe
B: moderately safe
C: moderately unsafe
D: highly unsafe

Example of Result of Summary Inspection

Name of river system		XX River System		Name of river		XX River		Section		143.0 km~ 151.0 km		Ref. No.			
----------------------	--	-----------------	--	---------------	--	----------	--	---------	--	--------------------	--	----------	--	--	--

Distance (km)	143.0			144.0			145.0			146.0			147.0			148.0			149.0			150.0			151.0

Name of levee		Levee A		Levee B		Levee C				Levee D										
		Sandy		Clayey		Sandy				Clayey		Complex								
Right bank	1. Evaluation based on factors	Type of levee material	Sandy		Clayey		Sandy				Clayey		Complex							
		Type of foundation ground material	Sandy		Clayey		Sandy				Clayey		Sandy							
		Attention-requiring landform	Former river channel																	
		Year completed	During and after the second half of the 1950s																	
		Rating	c	d	c	b	a	c	c				b	a	c	c				
	(2)	Average hydraulic gradient	0.3																	
			0.2																	
			0.1																	
	2. Evaluation based on damage history	Duration of high water level	48 hours or more																	
		Rating	c	c	b	c	c	c	b	c	b	c	b	c	c					
Safety rating		C	D	D	C	C	B	C	B	C	C	C	B	C	B	C	B	A	B	C
3. Summary evaluation of safety	Damage history	Ground leakage																		
	Seepage control work section	Sheet pile waterstop																		
	Safety rating	D																		
		C	D		C	B	C	B	C				B	C	B	C	B	A	B	C

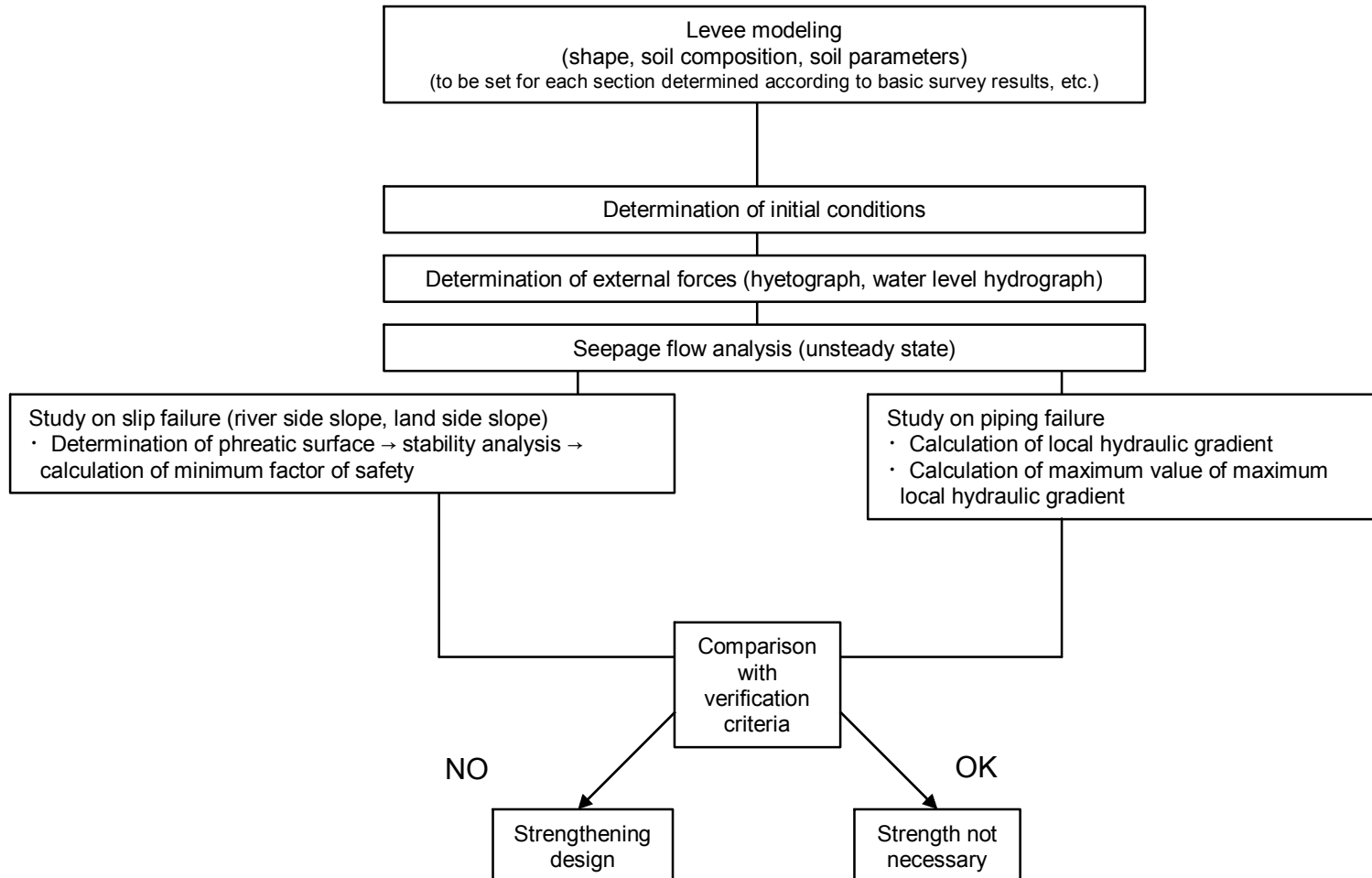
Date	Month, day, year	Regional Bureau name	XXXX Regional Bureau	Office name	XXXX Office
------	------------------	----------------------	----------------------	-------------	-------------

Design of Levees against Seepage



Nagara River, 1976

Safety Verification Procedure (for Seepage)



External Forces for Seepage Safety Verification and Verification Criteria

○ External forces for verification

- River-side water level for verification: design high water level
- Rainfall for verification: rainfall that causes project flood

○ Verification criteria

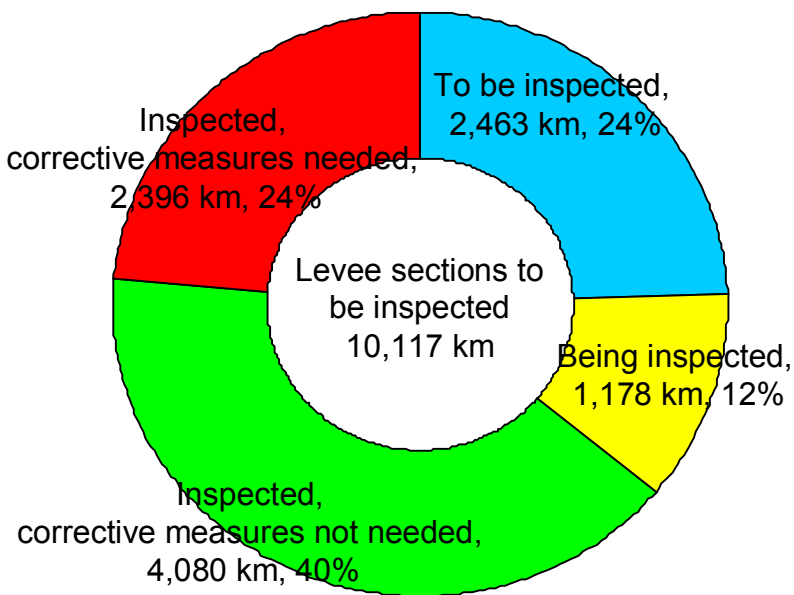
Safety from slip failure

- Land-side slope: factor of safety (F_s) $\geq 1.2 \times \alpha_1 \times \alpha_2$
 - α_1 : overdesign factor for complexity of levee history
 - For complex levee history $\alpha_1 = 1.2$
 - For simple levee history $\alpha_1 = 1.1$
 - For newly constructed levee $\alpha_1 = 1.0$
 - α_2 : overdesign factor for complexity of foundation ground
 - If there is damage history or attention-requiring landform $\alpha_2 = 1.1$
 - If there is no damage history or attention-requiring landform $\alpha_2 = 1.0$
- * "For complex levee history": This refers to a case where levee construction began many years ago and has been done in a number of stages or a case where the history of a levee is unknown.
- * "Attention-requiring landform": a landform that could result in an unstable state of a levee, such as a former river channel or a former flood-water pond
- River-side slope: factor of safety (F_s) ≥ 1.0

Safety from piping failure of foundation ground

- Without soil cover: maximum value of local hydraulic gradient (i) < 0.5
- With soil cover: weight of cover soil (G) $>$ uplift pressure (W)

State of Levee Inspection for Seepage Safety (State-managed Rivers, 2002 ~)



As of the end of December,
2006

Policy for the coming years



- By fiscal 2009, corrective measures will be taken for levee sections with a combined length of about 50 km that are particularly unsafe and have a history of damage.
- For other levee sections, monitoring activities such as patrol in times of flood will be continued. According to the results thus obtained, efforts will be made to strengthen levees and ensure success in flood-fighting activities.
- By fiscal 2009, the inspection of the remaining levee sections will be completed.

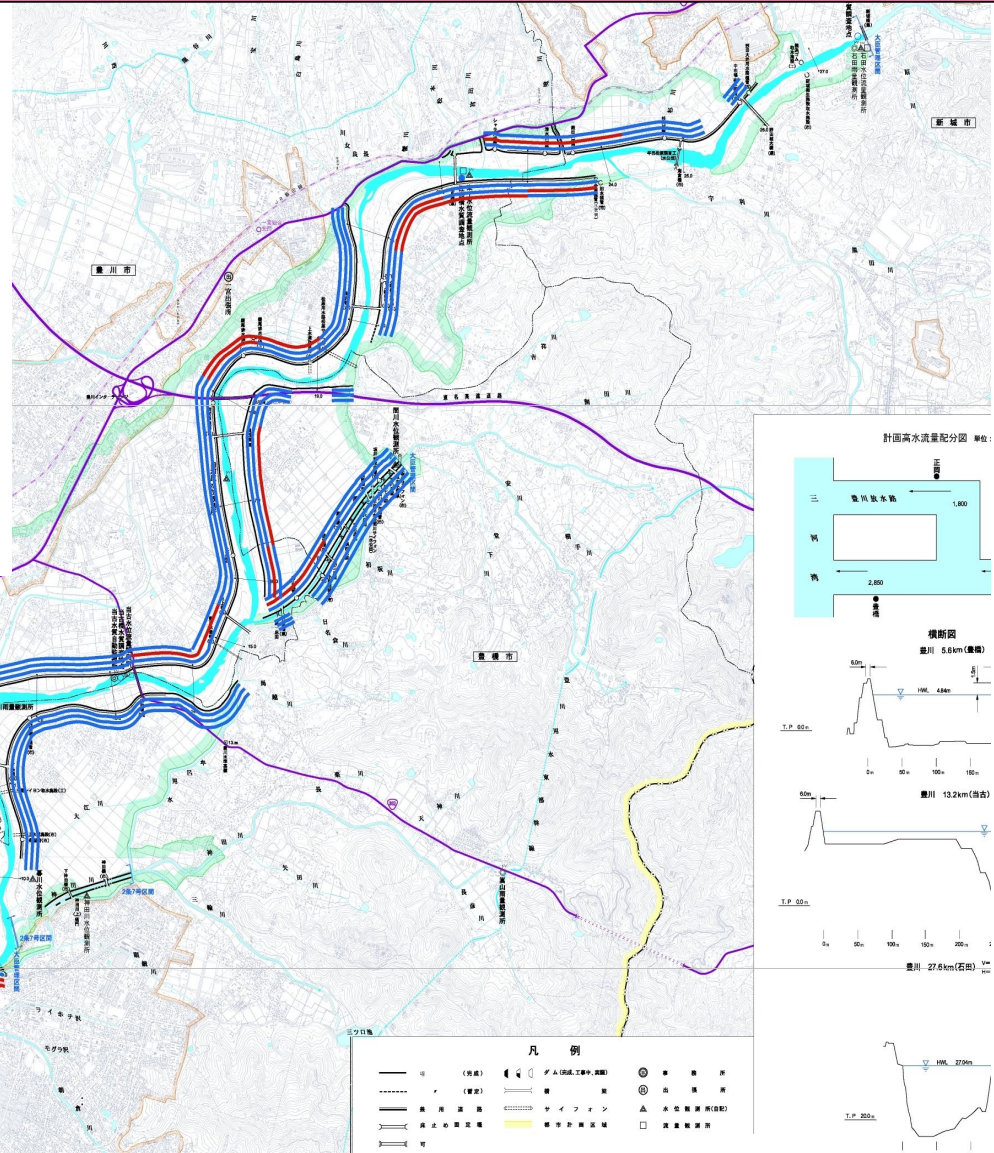
Example of publicized inspection results for Seepage Safety

Toyokawa Levees inspection results

Legend (seepage safety of levees)

River side of levee: safety from slip failure of river-side slope
Central part: safety from piping failure
Settled side of levee: safety from slip failure of land-side slope

-  not in conformity with safety verification criteria
-  in conformity with safety verification criteria
- Not indicated : levee section outside detailed inspection area

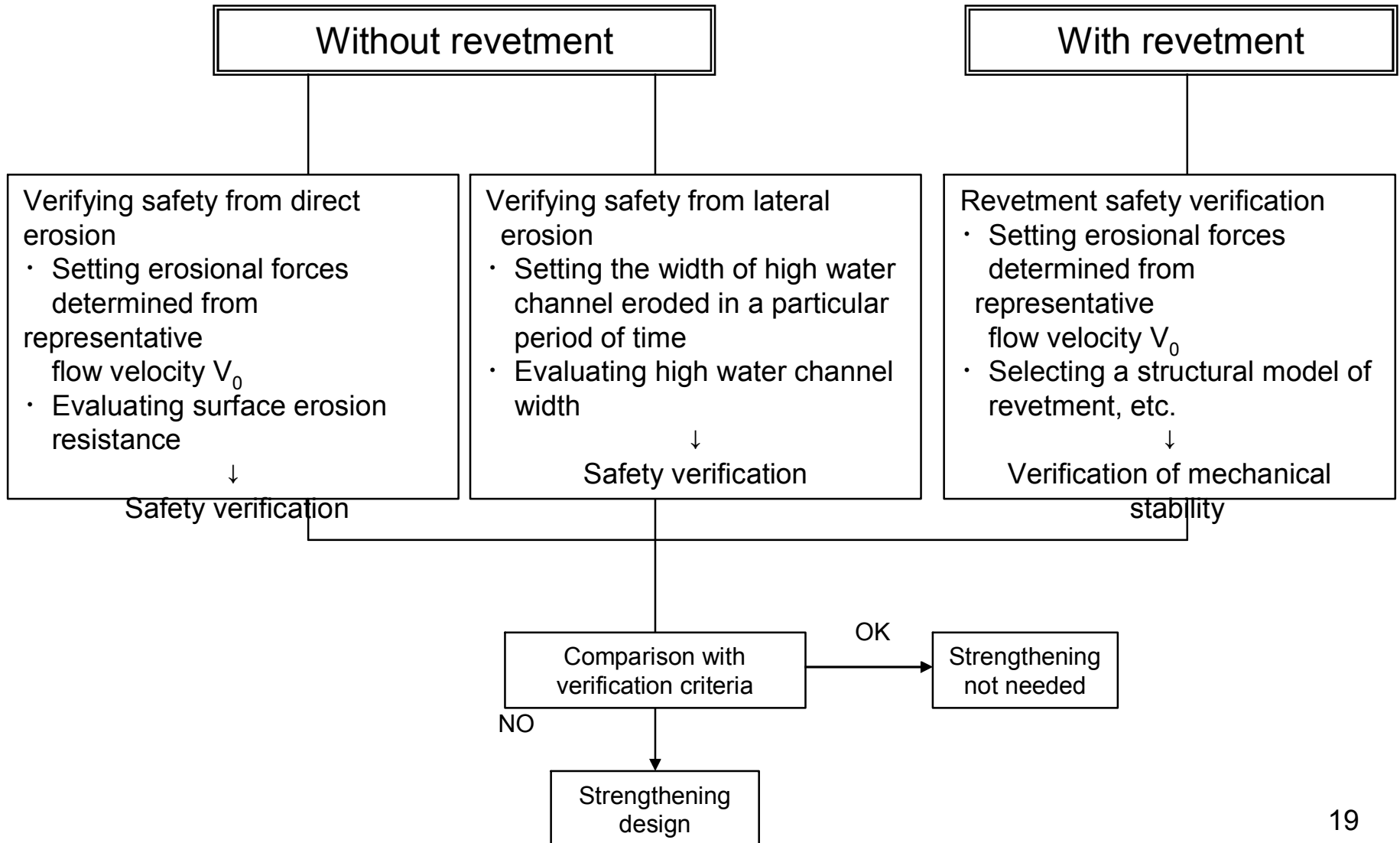


Levee Design against Erosion

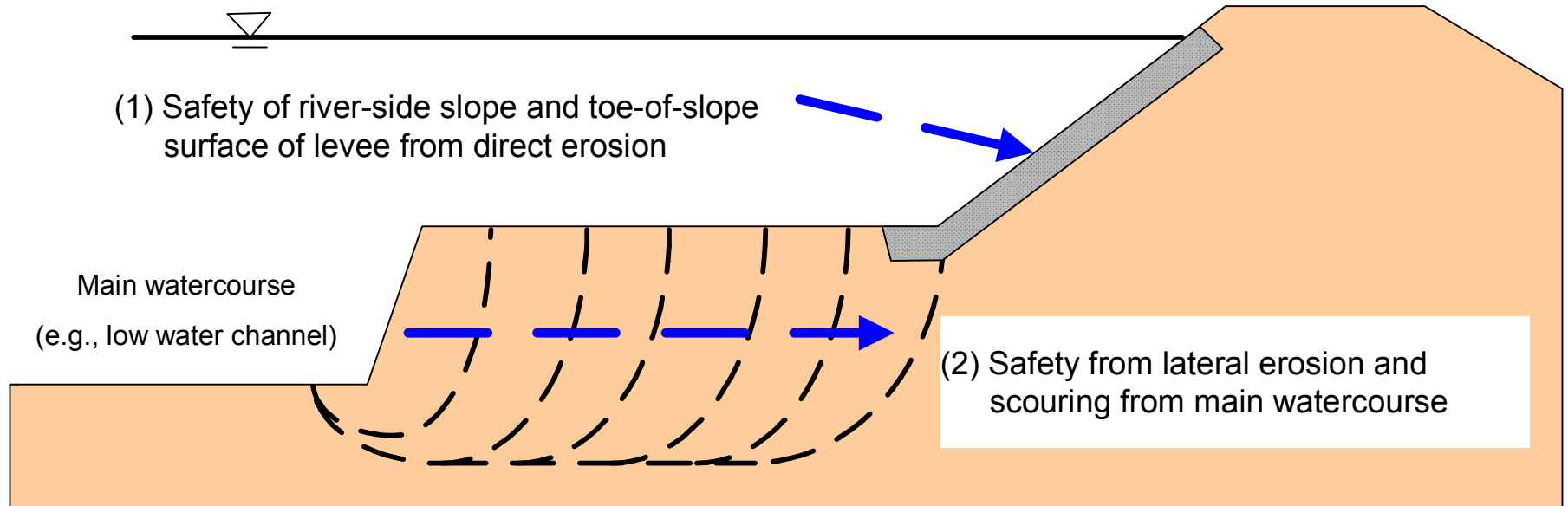


Ara River, 1998

Safety Verification Procedure (for Erosion)



External Forces for Erosion Safety Verification and Verification Criteria



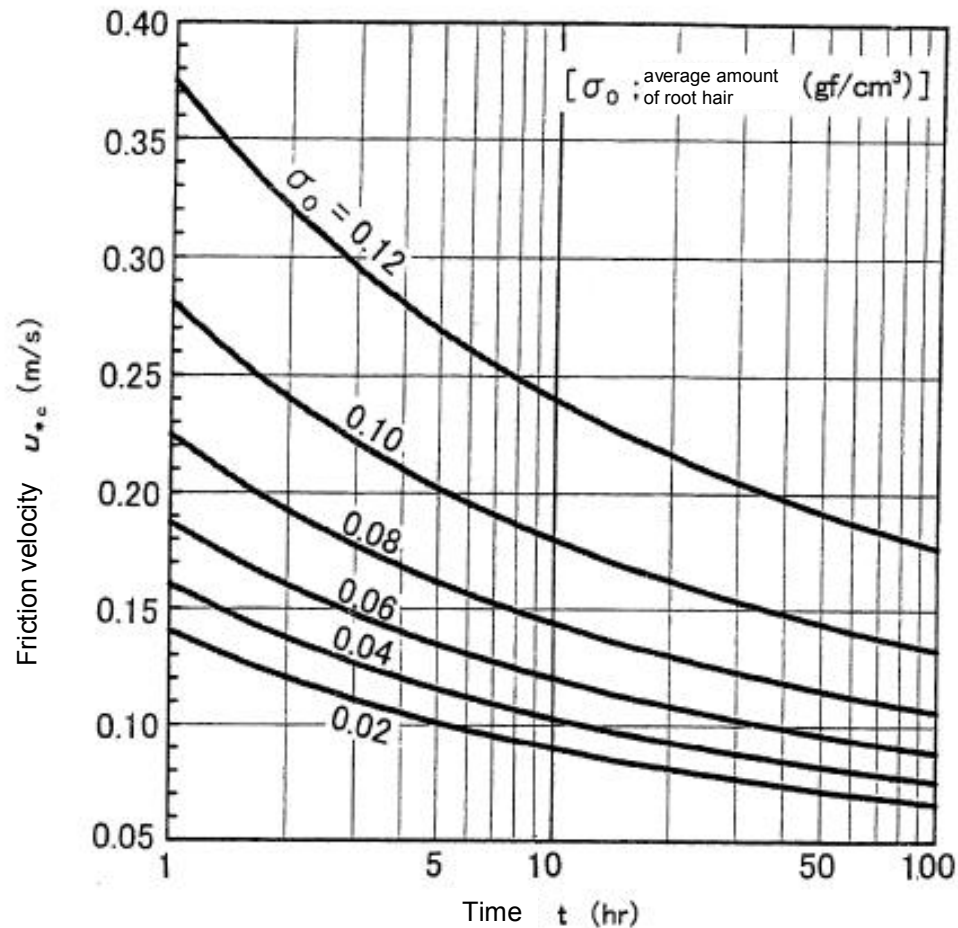
External forces for verification

- Setting **representative flow velocity**: calculated by multiplying the highest average flow velocity by a correction factor for curvature, etc.

Verification criteria

- (1) Safety from direction erosion of river-side slope and toe-of-slope surfaces of levee
 - **Surface erosion resistance > erosional force calculated from representative flow velocity**
- (2) Safety from lateral erosion and scouring from main watercourse
 - **Width of high water channel > width of high water channel eroded during verification period**

Surface Erosion Resistance

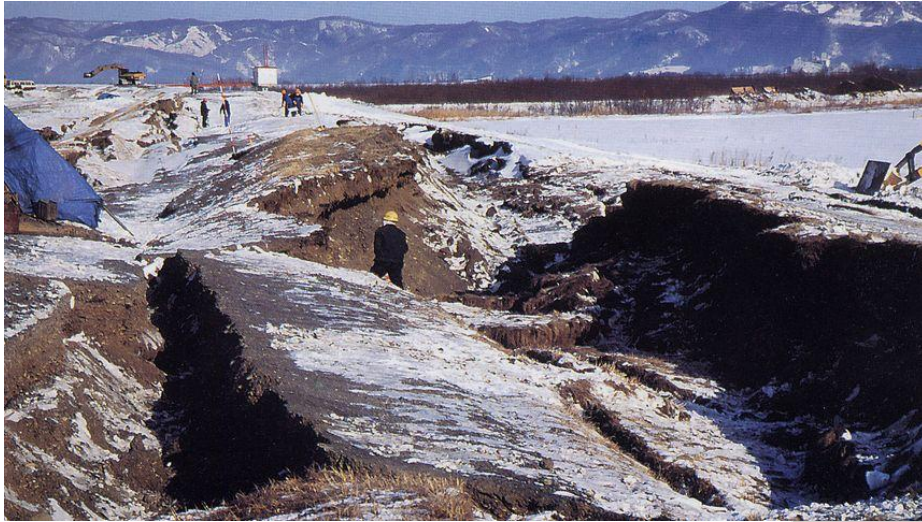


Surface erosion resistance of vegetation
(relationship between the amount of root hair and friction velocity)

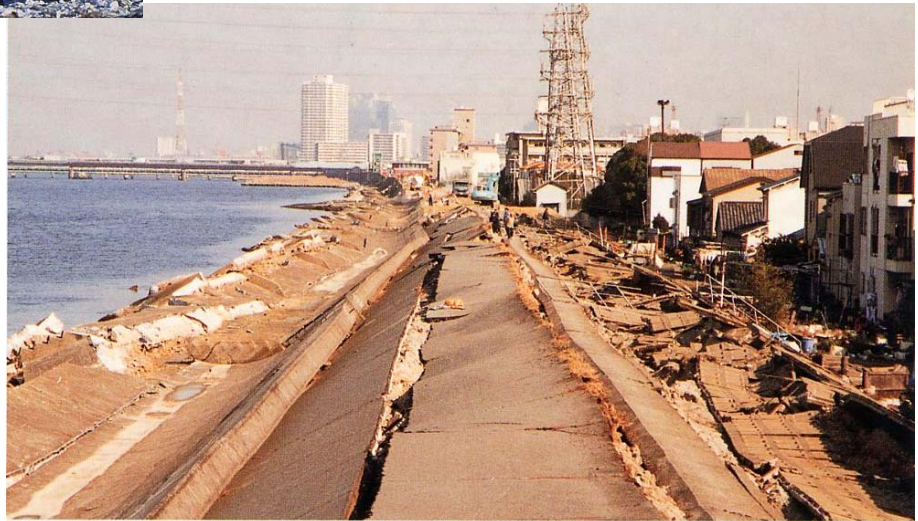
Verification Criteria for Safety from Scouring of Toe-of-slope Surface

River channel segment	Verification criteria (yardstick of width of high water channel eroded by single flood)
1	About 40 m
2-1	High water channel width $b > 5$ times low water channel bank height H
2-2 and 3	High water channel width $b > 2$ to 3 times low water channel bank height H

Seismic Design of Levees



Kushiro-oki Earthquake,
Tokachi River, 1993



Hyogoken Nanbu Earthquake,
Yodo River, 1995

Key Points of the Guideline for Verification of Seismic Performance of River Structures 2007

	Conventional seismic design		This guideline
Earthquake motion	Level 1 earthquake motion or equivalent	→	Level 1 earthquake motion Level 2 earthquake motion
Seismic performance	Damage is not permissible.	→	Level 1 earthquake motion Damage is not permitted. Level 2 earthquake motion A certain degree of damage is permitted according to functional requirements.
Verification method	Static verification method	→	Static verification method Dynamic verification method

Level 1 earthquake motion: earthquake motion whose probability of occurrence during the service life of a river structure is high

Level 2 earthquake motion: earthquake motion of an intensity that is thought to be the highest, both at the present and in future, at the location of interest

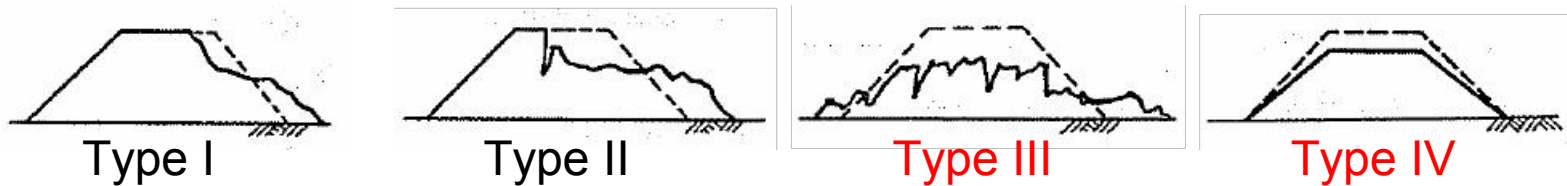
Level 2-1 earthquake motion: plate boundary earthquake (e.g., Kanto Earthquake of 1923)

Level 2-2 earthquake motion: inland near-field earthquake (e.g., Hyogoken Nanbu Earthquake of

1995)

Assumed Types of Levee Deformation and Verification Criteria

- **Type III and type IV deformations are assumed** because the levee crest could become lower than the river-side water level and emergency restoration is difficult to achieve.



○ Verification criteria

- It is confirmed that **the post-quake crest level is higher than the river-side water level (maximum water level in normal times) determined for seismic performance verification.**

Guidelines for Levee Monitoring

- Guideline for Levee Design (circular of the Director of River Improvement and Management Division, 2002)
- Technical Guideline for Levee Monitoring (circular of the Director of River Improvement and Management Division, 2002)
 - Describes standard monitoring methods needed to maintain and enhance the safety and reliability of levees against seepage and erosion at water levels not higher than HWL.
- Technical Document on Monitoring by Visual Inspection (JICE document, 2005)
 - Describes concrete monitoring methods, inspection result treatment methods, etc.

Levee Monitoring

- Two purposes

- Identifying weak spots in levees

Relatively unsafe areas are identified through patrol (visual inspection).

→ Management and information sharing by use of river inspection reports “River Karte” and monitoring information charts by visual inspection

- Verifying levee-strengthening techniques

Mainly by use of measuring instruments, the effectiveness of safety verification methods and levee-strengthening methods is verified.

→ Safety and reliability of levees are maintained and enhanced.

Standard Monitoring Items (Partial List)

	During flood	Immediately after flood	In normal times
In river channel		<ul style="list-style-type: none"> Abnormal conditions of groins, vane works, etc. 	<ul style="list-style-type: none"> Deep scours in curved sections, areas just downstream of river-crossing structures, etc.
High water channel, low water channel revetments	<ul style="list-style-type: none"> Erosion of high water channel Steps, eddies and bubbles on water surface 	<ul style="list-style-type: none"> Erosion of high water channel Abnormal conditions of low water channel revetments, etc. 	<ul style="list-style-type: none"> Abnormal conditions of foundations of low water channel revetments
Rive-side slope surface, high water channel revetments, levee revetments	<ul style="list-style-type: none"> Erosion and cracking of slope surfaces Abnormal conditions of revetments, etc. 	<ul style="list-style-type: none"> Erosion of high water channel Abnormal conditions of low water channel revetments, etc. 	<ul style="list-style-type: none"> Abnormal conditions of foundations of low water channel revetments
Crest	<ul style="list-style-type: none"> Cracks Puddles Cracks at ends of crest pavement 	<ul style="list-style-type: none"> Cracks Puddles Cracks at ends of crest pavement 	<ul style="list-style-type: none"> Cracks Existence or nonexistence of lower portions, etc.
Land-side slope surface	<ul style="list-style-type: none"> Abnormal conditions and cracking of slope surfaces Leakage in berm areas Muddiness of slope surfaces or berms, etc. 	<ul style="list-style-type: none"> Erosion and cracking of slope surface Bulging of slope surface, etc. 	<ul style="list-style-type: none"> The state of sodding, stomping by humans and animals, etc.
Land-side slope surface	• •	• •	• •
Channels at foot of levees	• •	• •	• •
Land-side area	• •	• •	• •
Near structures such as sluices	• •	• •	• •

River Inspection Report “River Karte” (Excerpts, Example)

作成年度：平成5年度

事務所：関東地建京浜工事事務所多摩出張所

調査対象区間：22k~23k

様式-1更新時

様式-1

平面図 スケール：S=1/5,000 測量年月：昭和60年3月

※様式-1に現地調査結果を転記した例

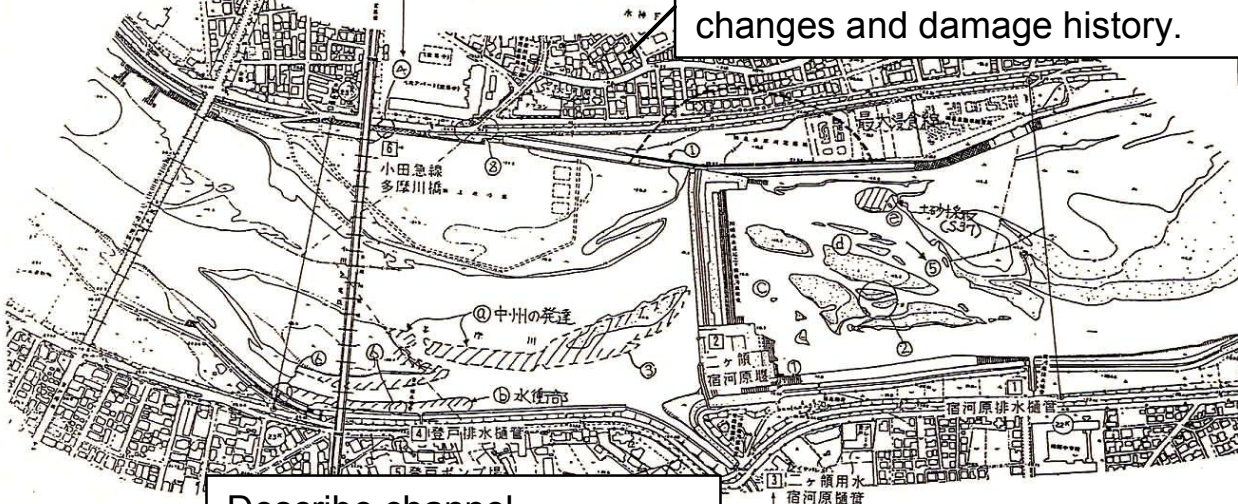
年度 出張所長氏名

5

9

Indicate the location and number corresponding to the site inspection results and Form 2.

Illustrate channel abnormalities or changes and damage history.



Describe channel abnormalities and changes.

Indicate permitted structures in orange.

Summarize damage history.

河道の異常・変調

- ①ミオ筋の変動状況
○宿河原堤上流側に中州の発達が見られる。
〔H 2.3〕航空写真③

Describe briefly (one-line comment) and refer to Form 2 for details.

- ②水街部の発生位置
○小田急線橋梁右岸側付近は湾曲の外周側であり、低水路線形が急角度で堤防法線に交わり、水街部が形成されている。⑤

- ③洗掘の状況
○④位置の水街部における河床洗掘は発達していない。
○宿河原堤下流は河床洗掘が進行し、22.2kと堰直下流の最深河床高の差は約6.7mである。④
〔定期横断面図〕
→①洗掘による根固めの乱れあり

- ④堤防の異常・変調（亀裂・漏水）
○実績なし
○①堤防が高くなっている
○②堤防が低くなっている

- ⑤その他
○堰下流部は土丹が露出している。④
○昭和37年に土砂採取の記録あり。④
○⑤急流になっている

主な被災履歴

- ① S49.9台風16号 (Q=4.101m³/s：石原) により被災。
□ 取付護岸の補修 (S60.3, S63.2) ~張石ブロック張替
② S49.9台風16号により被災
・堰本体：越流天端2ヶ所欠損
・左 岸：堰取付部決壊 (本体260m決壊)
③ S54.10 台風20号により堤脚保護工が被災 (Q=1.988m³/s：石原)
S57.9 台風18号により堤脚保護工が被災 (Q=2.726m³/s：石原)
④ 護岸が老朽化している

昭和62年度多摩川低水路是正計画検討

Monitoring Information Chart by Visual Inspection for State-managed Levees (Excerpts, Example)

Monitoring information chart by visual inspection for state-managed levees
(results of inspections before and after flood season)

Basic information

River system name		XX River System		River name	XX River	Section	XX bank XX km to XX km		Management office	XX River Office		Ref. No.			
Basic information	Levee	Distance		46	47	48	49	50	51	52	53	54	55		
		Influent/effluent rivers, main structures					Bridge			Sluice					
		Basic cross section	Not achieved		Achieved										
		Soil type	Levee	c	s	c	c	c	c	c	c	c	c	c	
			Foundation ground	c	c	c	s	c	c	c	s	c	c	c	
		Attention-requiring landforms										Former channel			
		Year completed	In or after 1955											Before 1955	
		Average hydraulic gradient	Less than 0.10	0.20~0.25	0.10~0.15	0.20~0.25	Less than 0.10	0.10~0.15							
		Duration of high water level	48 hours or more												
		Damage history and time	Leakage from levee (1969.8)												
		Corrective work section and time	Drain (1969)												
		Rough rating	A	C	B	D3	C	A	B	A	C	C			
		Detailed inspection	★ 2002 ★ 1998 ★ 1998 ★ 2000 ★ 2001												
	Detailed inspection results	Riverside													
		Landside													
		Local hydraulic gradient													
		G>W													
Revetment	Existence or nonexistence of revetment	High water channel revetment													
		Low water channel revetment													
		Foot protection works													
	Channel alignment	Curved section													
	History and time of revetment damage and bank erosion	Bank erosion (1963.7) Failure of low water channel revetment (1980.9)													
	Segment 1 section														
	Flow velocity 2 m/s or more	High water channel revetment													
		Low water channel revetment													
	Bank prone to flood-induced erosion														
Bed degradation tendency section															

Legend (levee inspection)



- : inspected
- : requiring inspection
- ★ : evaluated cross section
- Year conducted

Monitoring Information Chart by Visual Inspection for State-managed Levees (Excerpts, Example)

Results of inspection before flood season

Visual inspection information (date: XXXXX)	Priority section	Levee	Abnormality in attention-requiring item	Damage history Detailed inspection result: NG Abnormality in attention-requiring item	Levee-crossing structure	Attention-requiring landform Detailed inspection result: NG Abnormality in attention-requiring item	
		Revetment	Segment 1 Flow velocity 2 m/s or more Bed degradation tendency section	River-crossing structure	Levee-crossing structure Damage history Flow velocity 2 m/s or more	Abnormality in attention-requiring item	
	Levee (in normal times)	River-side slope					
		Crest	Lower portion on river-side (about 10 m long, 20 cm deep), lower portion in middle section (about 5 m long, 20 cm deep)				
		Land-side slope	Crack in slope surface above 2nd berm (5 m long, 2 cm wide), crack in slope surface above 1st berm (2 m long, 1 cm wide), many mole holes, etc. below 1st berm				
		Toe of land-side slope		Wetness of surface layer		Wetness of surface layer	
		Foot of levee					
		Structure			Wetness of surface layer between toe of slope and inspection passage		
	Revetment (in normal times)	High water channel					
		Lower water channel revetment		Abnormal condition of foundation of low water channel revetment			
Foundation/foot protection works							
High water channel revetment					Abnormal condition of high water channel revetment		
Channel (in normal times)	Tree growth	Willow trees in river channel (sparse)		Tall trees in right-bank high water channel (dense)			
	Sedimentation/ scouring	Sedimentation on left-bank side					
Remarks	Comment by flood fighters, etc.						

Legend (visual inspection)

 , section where there is abnormality in attention-requiring item
 , section where there is abnormality in other items

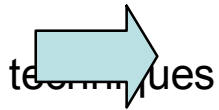
* Add visual inspection items on an as-needed basis according to characteristics of the river.

Prepare a similar chart after a flood.

Information to be updated every year

Tasks Ahead

Knowledge and important information newly acquired through disaster experience and maintenance activities will be integrated at key locations in a nationwide network. The objective is to build a system for feedback to local engineers.



Enhancing the reliability of levees by improving levee verification

and Qualitative improvement technology

